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LIQUID FLOW MEASUREMENT IN OPEN CHANNELS USING THIN PLATE WEIRS

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Indian Standard

LIQUID FLOW MEASUREMENT IN OPEN CHANNELS USING THIN PLATE WEIRS

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Indian Standard

LIQUID FLOW MEASUREMENT IN OPEN CHANNELS USING THIN PLATE WEIRS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 30 March 1979, after the draft finalized by the Fluid Flow Measurement Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Thin plate (notch) weirs offer a good means of gauging small flows (for example in laboratories, small open channels, etc) with a good degree of accuracy. However, very small changes in weir geometry, or flow and installation conditions would considerably affect the discharge coefficients and the accuracy, which will then necessitate periodic individual calibration. Therefore installation and maintenance of these weirs are also important.

0.3 In the formulation of this standard due weightage has been given to international coordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. This has been met by basing the standard on ISO 1438/I Water flow measurement in open channels using weirs and venturi flumes — Part I : Thin plate weirs, issued by the International Organization for Standardization.

0.4 This standard is one of the series of Indian Standards on instruments used in stream gauging. Other standards in the series are:

IS : 6059-1971 Recommendation for liquid flow measurement in open channels by weirs and flumes — weirs of finite crest width for free discharge

IS : 6062-1971 Method of measurement of flow of water in open channels using standing wave flume-fall

IS : 6063-1971 Method of measurement of flow of water in open channels using standing wave flume

IS : 6330-1971 Recommendation for liquid flow measurement in open channels by weirs and flumes — end depth method for estimation of flow in rectangular channels with a free overfall (approximate method)

IS : 9117-1979 Recommendation for liquid flow measurement in open channels by weirs and flumes — end depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method)

0.5 In reporting the results of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard specifies methods for measurement of water flow in open channels using rectangular and triangular-notch (V-notch) thin-plate weirs. The flow conditions considered are limited to steady, free and fully ventilated discharge of clear water. Recommended discharge coefficients are applicable to water only in the approximate range of temperatures from 5 to 40°C. Using the coefficients for water temperatures several degrees outside this range will result in negligible error except at very small heads. Limitations of applicability related to weir and flow geometry are specified for the recommended formulae.

2. DEFINITIONS

2.1 For the purpose of this standard, the definitions given in IS : 1191-1971† shall apply. Terms which have special significance in this standard are defined where they first occur.

3. UNITS OF MEASUREMENT

3.1 Units used in this standard are SI units.

4. PRINCIPLE

4.1 The discharge over thin-plate weirs is a function of the head on the weir, the size and shape of the discharge area, and an experimentally determined coefficient which takes into account the head on the weir, the geometrical properties of the weir and approach channel and physical properties of water and characteristics of flow.

5. INSTALLATION

5.1 General — General requirements of weir installations are described in the following clauses. Special requirements of different types of weirs are described in clauses which deal with specific weirs (*see* **8** and **9**).

*Rules for rounding off numerical values (*revised*).

†Glossary of terms and symbols used in connection with the measurement of liquid flow with a free surface (*first revision*).

5.2 Selection of Site — The type of weir to be used for discharge measurement is determined in part by the nature of the proposed measuring site. Under some conditions of design and use, weirs shall be located in rectangular flumes or in weir boxes which simulate flow conditions in rectangular flumes. Under other conditions, weirs may be located in natural channels as well as flumes or weir boxes, with no significant difference in measurement accuracy. Specific site-related requirements of the installation are described in **5.3**.

5.3 Installation Conditions

5.3.1 *General* — Weir discharge is critically influenced by the physical characteristics of the weir and the weir channel. Thin-plate weirs are especially dependent on installation features which control the velocity distribution in the approach channel and on the construction and maintenance of the weir crest in meticulous conformance with standard specifications.

5.3.2 *Weir* — Thin-plate weirs shall be vertical and perpendicular to the walls of the channel. The intersection of the weir plate with the walls and floor of the channel shall be watertight and firm, and the weir shall be capable of withstanding the maximum flow without distortion or damage.

Stated practical limits associated with different discharge formulae such as minimum width, minimum weir height, minimum head, and maximum values of h/p and b/B (where h is the measured head, p is the height of crest relative to floor, b is measured width of the notch and B is the width of the approach channel), are factors which influence both the selection of weir type and the installation.

5.3.3 *Approach Channel* — For the purposes of this standard the approach channel is that portion of the weir channel which extends upstream from the weir a distance not less than ten times the width of the nappe at maximum head at the weir. If the weir is located in a weir box, the length of the box shall be equal to the specified length of the approach channel.

The flow in the approach channel shall be uniform and steady, with the velocity distribution approximating that in a channel of sufficient length to develop normal (resistance-controlled) flow in smooth, straight channels. Figure 1 shows measured normal velocity distributions at the head measuring section in rectangular channels, upstream from the influence of a weir. Baffles and flow straighteners can be used to obtain normal velocity distribution, but their location with respect to the weir shall be not less than the minimum length prescribed for the approach channel.

The influence of approach-channel velocity distribution on weir flow increases as h/p and b/B increase in magnitude. If a weir installation unavoidably results in a velocity distribution which is appreciably non-uniform, the possibility of error in calculated discharge should be checked by means of an alternative discharge-measuring method for a representative range of discharges.

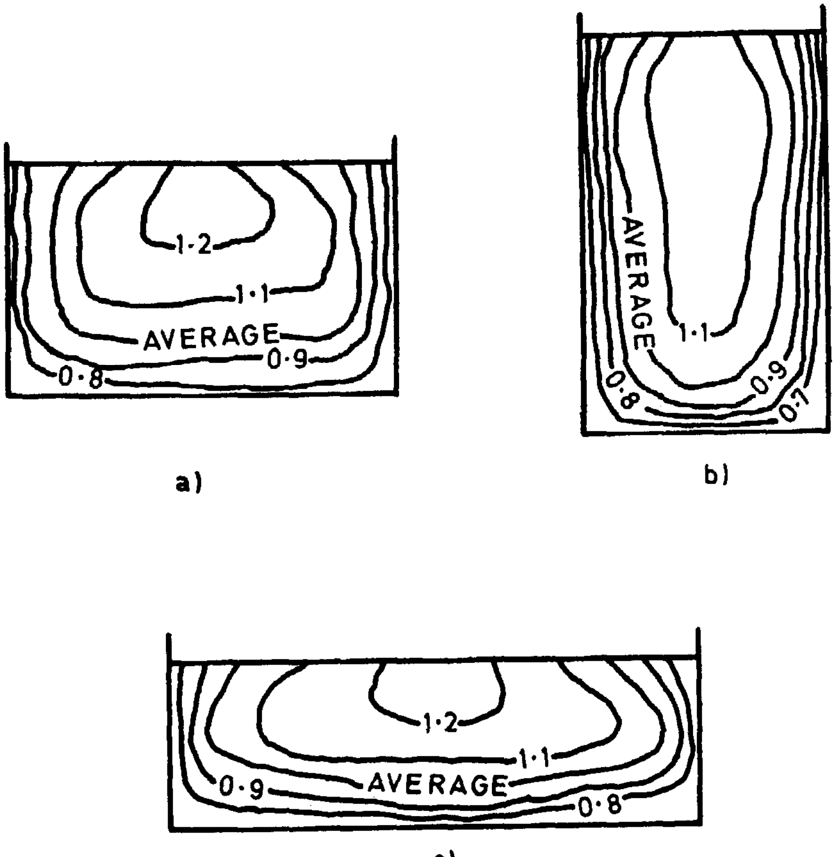


Fig. 1 Examples of Normal Velocity Distribution in Rectangular Channels

5.3.4 *Downstream Channel* — The shape and size of the channel downstream from the weir is of no significance, but the level of the water in the downstream channel shall be a sufficient vertical distance below the crest to ensure free, fully ventilated discharges. Free (non-submerged) discharge is ensured when the discharge is independent of the downstream water level. Full ventilation is ensured when the air pressure on the lower surface of the nappe is fully atmospheric.

6. MEASUREMENT OF HEAD

6.1 Head Measuring Devices — In order to obtain discharge measurement accuracies specified for the standard weirs, the head on the weir shall be measured with a laboratory-grade hook gauge, point gauge, manometer, or other gauge of equivalent accuracy. For a continuous record of head variations, precise float gauges and servo-operated point gauges can be used. Staff and tape gauges can be used when less accurate measurements are acceptable.

6.2 Stilling Well — Generally, to avoid water-level variations caused by waves, turbulence or vibration, the headwater level should be measured in a stilling well. When surface velocities and disturbances in the approach channel are negligible, the headwater level can be measured directly (for example, by means of a point gauge mounted over the headwater surface).

Stilling wells are connected to the approach channel by means of a suitable conduit, equipped if necessary with a throttle valve to damp oscillations. At the channel end of the conduit, the connection is made to floor or wall piezometers or a static tube located at the head-measurement section.

6.3 Head-Measurement Section — The head-measurement section shall be located a sufficient distance upstream from the weir to avoid the region of surface draw-down caused by the formation of the nappe. On the other hand, it shall be sufficiently close to the weir that the energy loss between the head-measurement section and the weir is negligible. For the weirs included in this standard the location of the head-measurement section will be satisfactory if it is at a distance equal to 4 to 5 times the maximum head (4 to 5 h_{max}) upstream from the weir.

If high velocities occur in the approach channel or if water-surface disturbances or irregularities occur at the head-measurement section because of high values of h/p or b/B, it may be necessary to install several pressure intakes to ensure that the head measured in the stilling well is the average of the heads at the several measurement points.

6.4 Head-Gauge Datum (Gauge Zero) — Accuracy of head measurements is critically dependent upon the determination of the head-gauge datum or gauge zero, which is defined as the gauge reading corresponding to the level of the weir crest (rectangular weirs) or the level of the vertex of the notch (triangular-notch weirs). When necessary, the gauge zero shall be checked. Numerous acceptable methods of determining the gauge zero are in use. Typical methods are described in subsequent clauses dealing specifically with rectangular and triangular weirs (*see* **8** and **9**).

Because of surface tension, the gauge zero cannot be determined with sufficient accuracy by reading the head gauge with the water in the approach channel drawn down to the apparent crest (or notch) level.

7. MAINTENANCE

7.1 Maintenance of the weir and the weir channel is necessary to ensure accurate measurements.

7.2 The approach channel shall be kept free of silt, vegetation and obstructions which might have deleterious effects on the flow conditions specified for the standard installation. The downstream channel shall be kept free of obstructions which might cause submergence or inhibit full ventilation of the nappe under all conditions of flow.

7.3 The weir plate shall be kept clean and firmly secured. In the process of cleaning, care shall be taken to avoid damage to the crest or notch, particularly the upstream edges and surfaces. Construction specifications for these most sensitive features should be reviewed before maintenance is undertaken.

7.4 Head-measurement piezometers, connecting conduits and the stilling well shall be cleaned and checked for leakage. The hook or point gauge, manometer, float or other instrument used to measure the head shall be checked periodically to ensure accuracy.

8. PROVISIONS FOR VENTILATED FREE FLOW

8.1 Provisions for ventilation of the nappe should ensure that the pressure under the nappe surface is atmospheric. The tail water level should be low enough not to interfere with the ventilation or free discharge of the nappe.

NOTE — Free (unsubmerged) flow is defined here as a flow which is independent of variations in tail water level. It is recommended that the tail water level should be preferably 0·1 m below the lowest point of the notch. It is recommended that the ventilating pipes, if any, should have an area of at least 1/150 of the maximum water area in the notch.

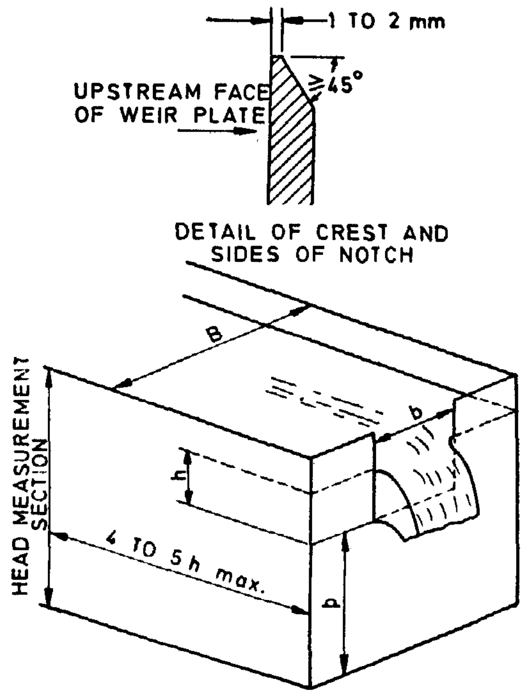


FIG. 2 RECTANGULAR-NOTCH, THIN-PLATE WEIR

9. RECTANGULAR THIN-PLATE WEIR

9.1 Types — The rectangular thin-plate weir is a general classification in which the rectangular-notch weir is the basic form and the full width weir is a limiting case. A diagrammatic illustration of the basic weir form is shown in Fig. 2 with intermediate values of b/B and h/p. When $b/B = 1{\cdot}0$, for example, when the width of the weir (b) is equal to the width of the channel at the weir section (B), the weir is of full width type (also referred to as a 'suppressed' weir, because its nappe lacks side contractions).

9.2 Specifications for the Standard Weir — The basic weir form consists of a rectangular notch in a vertical, thin plate. The plate shall be plane and rigid and perpendicular to the walls and the floor of the

approach channel. The upstream face of the plate shall be smooth (it shall be equivalent in surface finish to that of rolled sheet-metal).

The vertical bisector of the notch shall be equidistant from the two walls of the channel. The crest surface of the notch shall be a horizontal, plane surface, which shall form a sharp edge at its intersection with the upstream face of the weir plate. The width of the crest surface, measured perpendicular to the face of the plate, shall be between 1 and 2 mm. The side surfaces of the notch shall be vertical, plane surfaces which shall make sharp edges at their intersection with the upstream face of the weir plate. For the limiting case of the full-width weir, the crest of the weir shall extend to the walls of the channel, which in the vicinity of the crest shall be plane and smooth at least up to the measuring section (*see also* **9.3**).

To ensure that the upstream edges of the crest and the sides of the notch are sharp, they shall be machined or filed, perpendicular to the upstream face of the weir plate, free of burrs or scratches and untouched by abrasive cloth or paper. The downstream edges of the notch shall be chamfered if the weir plate is thicker than the maximum allowable width of the notch surface. The surface of the chamfer shall make an angle of not less than 45° with the crest and side surfaces of the notch (*see* Fig. 2). The weir plate in the vicinity of the notch preferably shall be made of corrosion-resistant metal; but if it is not, all specified smooth surfaces and sharp edges shall be kept coated with a thin, protective film (for example, oil, wax, silicone) applied with a soft cloth.

9.3 Specifications for Installation — The specifications stated in **5.3** shall apply. In general, the weir shall be located in a straight, horizontal, rectangular approach channel if possible. However, if the effective opening of the notch is so small in comparison with the area of the upstream channel that the approach velocity is negligible, the shape of the channel is not significant. In any case, the flow in the approach channel shall be uniform and steady, as specified in **5.3.3**.

If the width of the weir is equal to the width of the channel at the weir section (that is a full-width weir), the sides of the channel upstream from the plane of the weir shall be vertical, plane, parallel and smooth (equivalent in surface finish to that of a neat cement). The sides of the channel above the level of the crest of a full-width weir shall extend at least 0·3 h_{max} downstream from the plane of the weir. Fully ventilated nappe shall be ensured as specified in **5.3.4**.

The approach channel floor shall be smooth, flat and horizontal when the height of the crest relative to the floor (p) is small and/or h/p is large. For rectangular weirs, the floor should be smooth, flat and horizontal, particularly, when p is less than 0·05 m and/or h_{max}/p is greater than 1. Additional conditions are specified in connection with the recommended discharge formulae.

9.4 Specifications for Head Measurement

9.4.1 *General* — The conditions specified in **6.1**, **6.2** and **6.3** shall apply without exception.

9.4.2 *Determination of Gauge Zero* — The head-gauge datum or gauge zero shall be determined with great care, and it shall be checked when necessary. A typical, acceptable method of determining the gauge zero for rectangular weirs is described as follows:

a) Still water in the approach channel is drawn to a level below the weir crest;

b) A temporary hook gauge is mounted over the approach channel, a short distance upstream from the weir crest;

c) A precise machinists' level is placed with its axis horizontal, with one end lying on the weir crest and the other end on the point of the temporary hook gauge (the gauge having been adjusted to hold the level in this position). The reading of the temporary gauge is recorded;

d) The temporary hook gauge is lowered to the water surface in the approach channel and its reading is recorded. The permanent gauge is adjusted to read the level in the stilling well, and this reading is recorded; and

e) The computed difference between the two readings of the temporary gauge is added to the reading of the permanent gauge. The sum is the gauge zero for the permanent gauge.

Figure 3 illustrates the use of this procedure with a form of temporary hook gauge which is conveniently mounted on the weir plate.

9.5 Discharge Formulae — General — Recommended discharge formulae for rectangular thin-plate weirs are presented in two categories:

a) formulae for the basic weir form (all values of b/B), and

b) formulae for full-width weirs ($b/B = 1{\cdot}0$).

Common symbols used in the formulae are defined as follows:

Q = volume rate of flow in cubic metres per second,

C = coefficient of discharge (non-dimensional),

g = acceleration due to gravity in metres per second squared,

b = measured width of the notch in metres,

B = width of the approach channel in metres,

h = measured head in metres, and

p = height of the crest relative to the floor in metres.

Additional, special symbols are defined following their first occurrence in a formula.

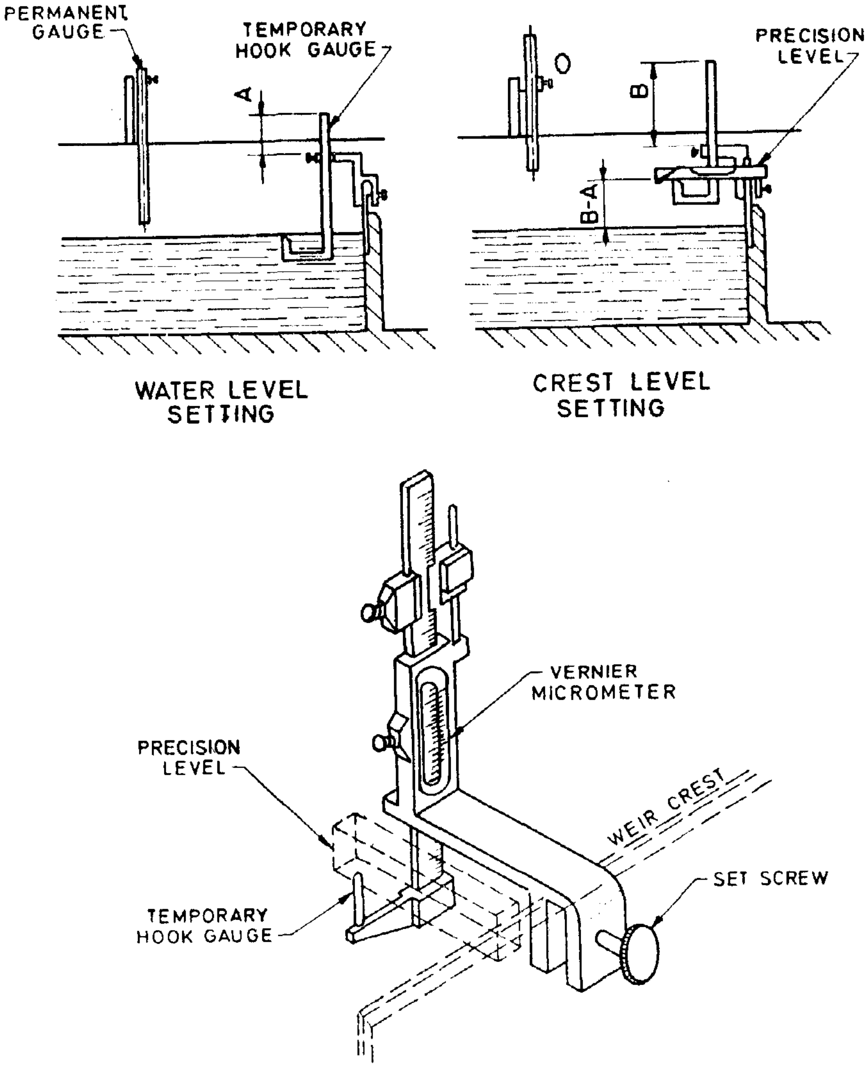


FIG. 3 DETERMINATION OF GAUGE ZERO FOR RECTANGULAR WEIR

9.6 Formulae for the Basic Weir Form (All Values of b/B)

9.6.1 *Kindsvater-Carter Formula*

The Kindsvater-Carter formula for the basic weir form is:

$$Q = C_e \frac{2}{3} \sqrt{2g}\, b_e\, h_e^{3/2} \quad \text{... (1)}$$

where

C_e = coefficient of discharge,

b_e = effective width, and

h_e = effective head.

The coefficient of discharge C_e has been determined by experiment as a function of two variables from the formula:

$$C_e = f\left(\frac{b}{B}, \frac{h}{p}\right) \quad \text{... (2)}$$

The effective width and head are defined by the equations:

$$b_e = b + k_b \quad \text{... (3)}$$

$$h_e = h + k_h \quad \text{... (4)}$$

in which k_b and k_h are experimentally determined quantities, in metres, which compensate for the combined effects of viscosity and surface tension.

9.6.1.1 *Evaluation of C_e, k_b and k_h* — Figure 4 shows experimentally determined values of C_e as a function of h/p for representative values of b/B. Values of C_e for intermediate values of b/B can be determined by interpolation.

Figure 5 shows values of k_b, which have been experimentally determined as a function of b/B.

Experiments have shown that k_h can be taken to have a constant value of 0·001 m for weirs constructed in strict conformance with recommended specifications.

9.6.1.2 *Formulae for C_e* — For specific values of b/B the relationship between C_e and h/p has been shown by experiment (*see* Fig. 4) to be of the linear form:

$$C_e = a + a'\left(\frac{h}{p}\right)$$

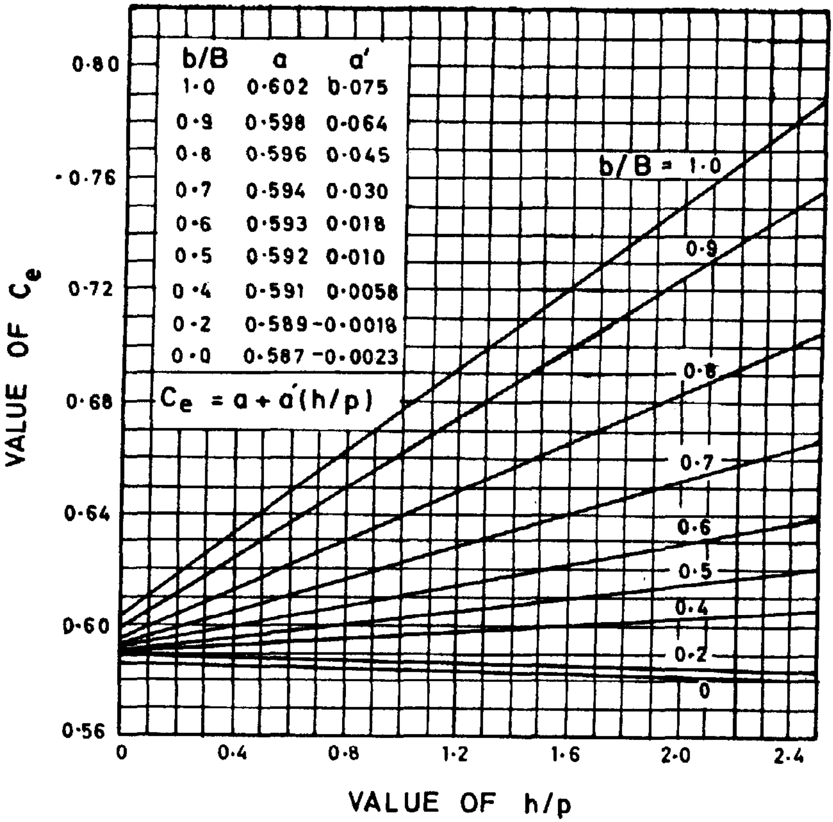
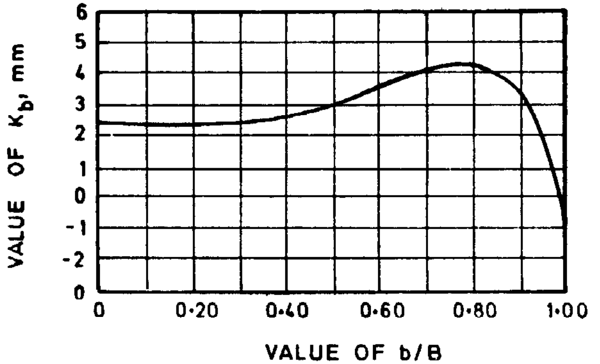


FIG. 4 COEFFICIENT OF DISCHARGE $C_e = a + a' (h/p)$



b/B	k_b mm
0	2·4
0·2	2·4
0·4	2·7
0·6	3·6
0·8	4·2
1·0	−0·9

FIG. 5 VALUE OF k_b RELATED TO b/B

Thus, for the values of b/B shown on Fig. 4, formulae for C_e can be written as follows:

$$(b/B = 1{\cdot}0): C_e = 0{\cdot}602 + 0{\cdot}075 \frac{h}{p} \quad \dots (5)$$

$$(b/B = 0{\cdot}9): C_e = 0{\cdot}598 + 0{\cdot}064 \frac{h}{p} \quad \dots (6)$$

$$(b/B = 0{\cdot}8): C_e = 0{\cdot}596 + 0{\cdot}045 \frac{h}{p} \quad \dots (7)$$

$$(b/B = 0{\cdot}7): C_e = 0{\cdot}594 + 0{\cdot}030 \frac{h}{p} \quad \dots (8)$$

$$(b/B = 0{\cdot}6): C_e = 0{\cdot}593 + 0{\cdot}018 \frac{h}{p} \quad \dots (9)$$

$$(b/B = 0{\cdot}4): C_e = 0{\cdot}591 + 0{\cdot}005\,8 \frac{h}{p} \quad \dots (10)$$

$$(b/B = 0{\cdot}2): C_e = 0{\cdot}589 - 0{\cdot}001\,8 \frac{h}{p} \quad \dots (11)$$

$$(b/B = 0): C_e = 0{\cdot}587 - 0{\cdot}002\,3 \frac{h}{p} \quad \dots (12)$$

For intermediate values of b/B, formulae for C_e can be determined satisfactorily by interpolation.

9.6.1.3 *Practical limitations on h/p, h, b and p* — Practical limits are placed on h/p because head measurement difficulties and errors result from surges and waves which occur in the approach channel at larger values of h/p. Limits are placed on h to avoid the 'clinging nappe' phenomenon which occurs at very low heads. Limits are placed on b because of uncertainties regarding the combined effects of viscosity and surface tension represented by the quantity of k_b at very small values of b. Limits are placed on p and $B-b$ to avoid the instabilities which result from eddies that form in the corners between the channel boundaries and the weir when values of p and $B-b$ are small.

For conservative practice, limitations applicable to the use of the Kindsvater-Carter formula are:

a) h/p shall be not greater than 2·5;

b) h shall be not less than 0·03 m;

c) b shall be not less than 0·15 m;

d) p shall be not less than 0·10 m; and

e) either $(B-b)/2 = 0$ (full width weir) or $(B-b)/2$ shall not be less than 0·10 m (contracted weir).

9.6.2 *SIA* Formula*

The SIA formula for the basic weir form is:

$$Q = C \frac{2}{3} \sqrt{2g}\, b\, h^{3/2} \qquad \ldots(13)$$

in which

$$C = \left[0{\cdot}578 + 0{\cdot}037\left(\frac{b}{B}\right)^2 + \frac{0{\cdot}003\,615 - 0{\cdot}003\,0\left(\frac{b}{B}\right)^2}{h + 0{\cdot}001\,6}\right] \times \left[1 + 0{\cdot}5\left(\frac{b}{B}\right)^4\left(\frac{h}{h+p}\right)^2\right] \qquad \ldots(14)$$

Practical limitations applicable to the use of the SIA formula are:

a) h/p shall be not greater than 1·0;

b) b/B shall be not less than 0·3;

c) h shall be not less than 0·025 B/b and not greater than 0·80 m; and

d) p shall be not less than 0·30 m.

For full-width weirs equation 14 reduces to:

$$C = \left[0{\cdot}615 + \frac{0{\cdot}000\,615}{h + 0{\cdot}001\,6}\right]\left[1 + 0{\cdot}5\left(\frac{h}{h+p}\right)^2\right] \qquad \ldots(15)$$

*Société Suisse des Ingénieurs et Architectes.

9.7 Formulae for Full-Width Weirs ($b/B = 1\cdot0$) — In addition to formulae 5 and 15, which represent the limiting case of $b/B = 1\cdot0$ in the Kindsvater-Carter and SIA formulae for weirs of the basic form, the following formulae are recommended for $b/B = 1\cdot0$ only.

9.7.1 *Rehbock Formula (1929)* — The Rehbock formula in the form proposed in 1929 is of the effective-head variety:

$$Q = C_e \frac{2}{3} \sqrt{2\,g}\, b\, h_e^{3/2} \quad ...(16)$$

in which

$$C_e = 0\cdot602 + 0\cdot083\, h/p \quad ...(17)$$

$$h_e = h + 0\cdot001\,2 \quad ...(18)$$

Practical limitations applicable to the use of the Rehbock formula are:

a) h/p shall be not greater than 1·0;

b) h shall be between 0·03 and 0·75 m;

c) b shall be not less than 0·30 m; and

d) p shall be not less than 0·10 m.

9.7.2 *IMFT* Formula*

The IMFT formula for full-width weir is:

$$Q = C \frac{2}{3} \sqrt{2\,g}\, b \left[h + \frac{V_a^2}{2g} \right]^{3/2} \quad ...(19)$$

in which

$$C = 0\cdot627 + 0\cdot018\,0 \left[\frac{h + \frac{V_a^2}{2g}}{p} \right] \quad ...(20)$$

in which, V_a is the average velocity in the approach channel, $V_a = Q/A_a$, where A_a is the area of the flow at the head-measurement section.

Because V_a is a function of Q, it must be computed by successive approximations.

Practical limitations applicable to the use of the IMFT formula are:

a) h/p shall be not greater than 2·5;

b) h shall be not less than 0·03 m;

*Institut de Mécanique des Fluides de Toulouse.

c) b shall be not less than 0·20 m; and

d) p shall be not less than 0·10 m.

9.8 Accuracy of Discharge Coefficient — Rectangular Weirs — The accuracy of discharge measurements made with a rectangular thin-plate weir depends primarily on the accuracy of the head and width measurements and on the applicability of the discharge formula and coefficients used. If great care is exercised in meeting the construction, installation, and operational conditions specified in this International Standard, uncertainties (at 95 percent confidence level) attributable to the coefficients of discharge will be not greater than 1·5 percent for values of h/p less than 1·0, not greater than 2 percent for values of h/p between 1·0 and 1·5 and not greater than 3 percent for values of h/p between 1·5 and 2·5. The specified uncertainties are applicable only if the additional restrictions on values of h, b, h/p, p, and $(B - b)/2$ given in **9.6** and **9.7** are applied. The combination of all uncertainties which contribute significantly to the uncertainty of discharge measurements is treated in **11**. Examples of estimated uncertainties in measured discharge are given in **12**.

10. TRIANGULAR-NOTCH THIN-PLATE WEIR

10.1 Specifications for the Standard Weir — The triangular-notch thin-plate weir consists of a V-shaped notch in a vertical, thin plate. A diagrammatic illustration of the triangular-notch weir is shown in Fig. 6. The weir plate shall be plane and rigid and perpendicular to the walls and the floor of the channel. The upstream face of the plate shall be smooth (in the vicinity of the notch it shall be equivalent in surface finish to that of rolled sheet-metal).

The bisector of the notch shall be vertical and equidistant from the two walls of the channel. The surfaces of the notch shall be plane surfaces, which shall form sharp edges at their intersection with the upstream face of the weir plate. The width of the notch surfaces, measured perpendicular to the face of the plate, shall be between 1 and 2 mm.

To ensure that the upstream edges of the notch are sharp, they shall be machined or filed, perpendicular to the upstream face of the plate, free of burrs or scratches and untouched by abrasive cloth or paper. The downstream edges of the notch shall be chamfered if the weir plate is thicker than the maximum allowable width of the notch surface. The surface of the chamfer shall make an angle of not less than 45° with the surface of the notch (*see* Fig. 6). The weir plate in the vicinity of the notch preferably shall be made of corrosion-resistant metal; but if it is not, all specified smooth surfaces shall be kept coated with a thin protective film (for example, oil, wax, silicon) applied with a soft cloth.

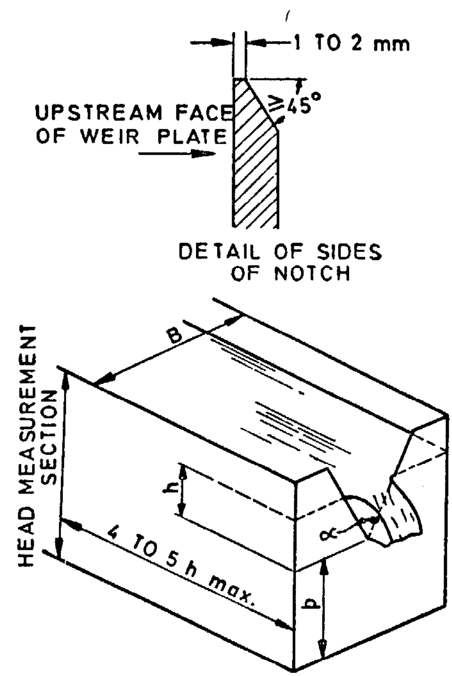


FIG. 6 TRIANGULAR-NOTCH, THIN-PLATE WEIR

10.2 Specifications for the Installation — The specifications stated in **5.3** shall apply. In general, the weir shall be located in a straight, horizontal, rectangular channel if possible. However, if the effective opening of the notch is so small in comparison with the area of the upstream channel that the approach velocity is negligible, the shape of the channel is not significant. In any case, the flow in the approach channel shall be uniform and steady, as specified in **5.3.3**.

If the top width of the nappe at maximum head is large in comparison with the width of the channel, the channel walls shall be straight, vertical and parallel. If the height of the vertex relative to the level of the floor is small in comparison with the maximum head, the channel floor shall be smooth, flat and horizontal. In general the approach channel should be smooth, straight and rectangular when B/b_{max} is less than 3 and/or h_{max}/p is greater than 1. Additional conditions are specified in connection with the recommended discharge formulae.

10.3 Specifications for Head Measurement

10.3.1 *General* — The conditions specified in **6.1**, **6.2** and **6.3** shall apply without exception.

10.3.2 *Determination of Notch Angle* — Precise head measurements for triangular-notch weirs require that the notch angle (angle included between sides of the notch) be measured accurately. One of several satisfactory methods is described as follows:

a) Two true discs of different, micrometered diameters are placed in the notch with their edges tangent to the sides of the notch.

b) The vertical distance between the centres (or two corresponding edges) of the two discs is measured with a micro-meter caliper.

c) The notch angle α is twice the angle whose sine is equal to the differences between the radii of the discs divided by the distance between the centres of the discs.

10.3.3 *Determination of Gauge Zero* — The head-gauge datum or gauge zero shall be determined with great care, and it shall be checked when necessary. A typical acceptable method of determining the gauge zero for triangular-notch weirs is described as follows:

a) Still water in the approach channel is drawn to a level below the vertex of the notch.

b) A temporary hook gauge is mounted over the approach channel, with its point a short distance upstream from the vertex of the notch.

c) A true cylinder of known (micrometered) diameter is placed with its axis horizontal, with one end resting in the notch and the other end balanced on the point of the temporary hook gauge. A machinists' level is placed on top of the cylinder, and the hook gauge is adjusted to make the cylinder precisely horizontal. The reading of the temporary gauge is recorded.

d) The temporary hook gauge is lowered to the water surface in the approach channel and the reading is recorded. The permanent gauge is adjusted to read the level in the stilling well, and this reading is recorded.

e) The distance (y) from the bottom of the cylinder to the vertex of the notch is computed with the known value of the notch angle (α) and the radius (r) of the cylinder $\left[y = \left(r/\sin \frac{\alpha}{2} \right) - r \right]$.

This distance is then subtracted from the reading recorded in (c), the result being the reading of the temporary gauge at the vertex of the notch.

f) The difference between the computed reading in (e) and the reading of the temporary gauge in (d) is added to the reading of the permanent gauge in (d). The sum is the gauge zero for the permanent gauge.

An advantage of this method is that it refers the gauge zero to the geometrical vertex which is defined by the sides of the notch.

10.4 Discharge Formulae — General — Recommended discharge formulae for triangular-notch thin-plate weirs are presented in two categories:

a) formula for all notch angles between 20° and 100°, and
b) formulae for specific notch angles (fully contracted weirs).

Common symbols used in the formulae are defined as follows:

Q = volume rate of flow in cubic metres per second;
C = coefficient of discharge (non-dimensional);
g = acceleration due to gravity in metres per second squared;
α = notch angle, that is, the angle included between the sides of the notch in degrees; and
h = measured head in metres.

Additional, special symbols are defined following their first occurrence in a formula.

10.5 Formula for All Notch Angles Between 20° and 100° — The Kindsvater-Shen formula for triangular notch weirs is:

$$Q = C_e \frac{8}{15} \tan \frac{\alpha}{2} \sqrt{2g}\, h_e^{5/2} \qquad \ldots (21)$$

in which

C_e = coefficient of discharge, and
h_e = effective head.

The coefficient of discharge C_e has been determined by experiment as a function of three variables (*see* Fig. 7).

$$C_e = f\left(\frac{h}{p}, \frac{p}{B}, \alpha\right) \qquad \ldots (22)$$

in which

p = height of the vertex of the notch with respect to the floor of the approach channel,

B = width of the approach channel,

h_e = defined by the equation,

$$h_e = h + k_h \qquad \ldots(23)$$

in which k_h is an experimentally determined quantity, in metres, which compensates for the combined effects of viscosity and surface tension.

10.5.1 *Evaluation of C_e and k_h* — For triangular weirs with notch angle α equal to 90°, Fig. 7 shows experimentally determined values of C_e for a wide range of values of h/p and p/B. For α = 90°, k_h has been shown to have a constant value of 0·000 85 m for a corresponding range of values of h/p and p/B.

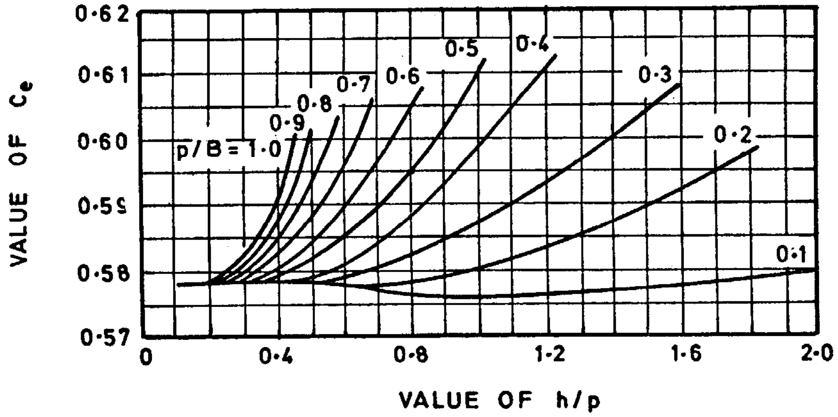


FIG. 7 COEFFICIENT OF DISCHARGE C_e (α=90°)

For notch angles other than 90°, experimental data are insufficient to define C_e as a function of h/p and p/B. However, for weir notches which are small relative to the area of the approach channel, the velocity of approach is negligible and the effects of h/p and p/B are also negligible. For this condition (the so-called 'fully-contracted' condition), Fig. 8 shows experimentally determined values of C_e as a function of α alone. Corresponding values of k_h are shown in Fig. 9.

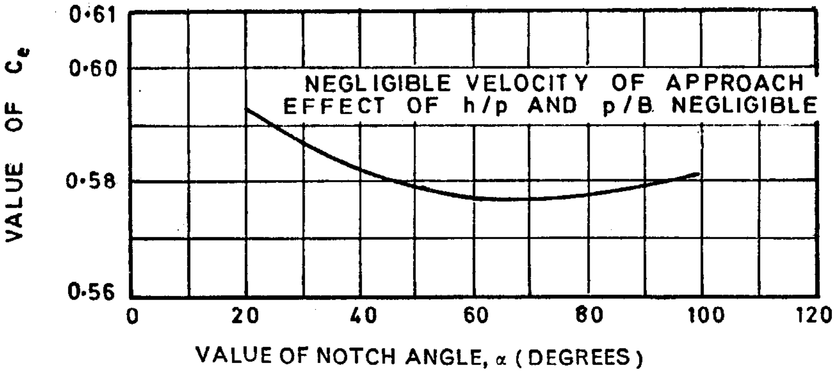


FIG. 8 COEFFICIENT OF DISCHARGE C_e RELATED TO NOTCH ANGLE α

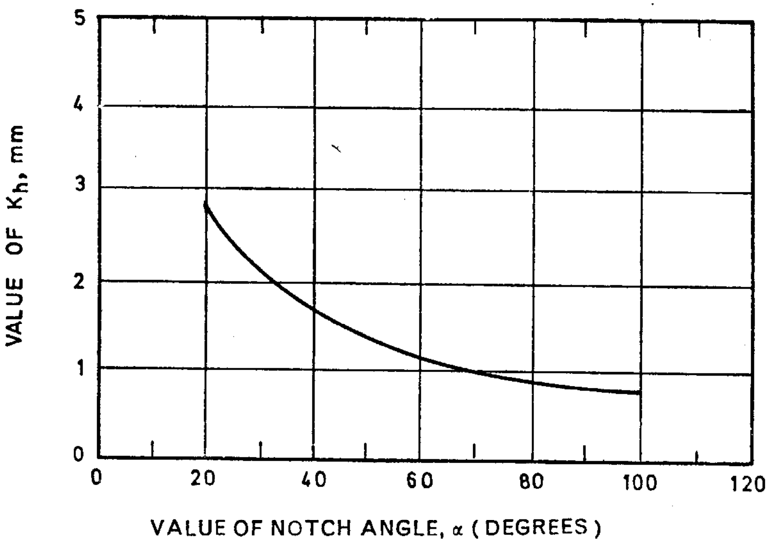


FIG. 9 VALUE OF k_h RELATED TO NOTCH ANGLE α

10.5.2 *Practical Limitations on α, h/p, p/B, h and p* — For reasons related to hazards of measurement-error and lack of experimental data, the following practical limits are applicable to the use of the Kindsvater-Shen formula:

a) α shall be between 20° and 100°;

b) h/p shall be limited to the range shown in Fig. 7 for $\alpha = 90°$ h/p shall be not greater than 0·35 for other values of α;

c) p/B shall be limited to the range shown in Fig. 7 for $\alpha = 90°$ p/B shall be between 0·10 and 1·5 for other values of α;

d) h shall be not less than 0·06 m;

e) p shall be not less than 0·09 m.

10.6 Formula for Specific Notch Angles (Fully Contracted Weir) — BSI* Formula for Three Related Angles — This formula is for notch angles which have a special geometric relationship to each other:

a) tangent $\alpha/2 = 1$ ($\alpha = 90°$);

b) tangent $\alpha/2 = 0{\cdot}50$ ($\alpha = 53°8'$); and

c) tangent $\alpha/2 = 0{\cdot}25$ ($\alpha = 28°4'$).

The BSI discharge formula is:

$$Q = C\frac{8}{15}\tan\frac{\alpha}{2}\sqrt{2\,g}\,h^{5/2} \quad \ldots(24)$$

and the experimentally determined values of C and Q for the condition of 'full contraction' are shown in Tables 1, 2 and 3.

Practical limitations applicable to the use of this formula are:

a) h/p shall be not greater than 0·4;

b) h/B shall be not greater than 0·2;

c) h shall be between 0·05 and 0·38 m;

d) p shall be not less than 0·45 m; and

e) B shall be not less than 1·0 m.

10.7 Accuracy of Discharge Coefficients — Triangular-Notch Weirs — The accuracy of discharge measurements made with a triangular-notch thin-plate weir depends primarily on the accuracy of the head and notch-angle measurements and on the applicability of the discharge formula and coefficients used. If great care is exercised in meeting the construction, installation, and operational conditions specified in this

*British Standards Institution.

standard, uncertainties (at 95 percent confidence level) attributable to the coefficients of discharge will be not greater than 1·0 percent. The combination of all uncertainties which contribute significantly to the uncertainty of discharge measurements is treated in **11**. Examples of estimated uncertainties in measured discharge are given in **12**.

11. ACCURACY OF DISCHARGE MEASUREMENTS

11.1 General — The accuracy of a discharge measurement is best expressed in terms of a statistically determined range of uncertainty. In this instance the measured discharge is the discharge calculated by means of a weir discharge formula, and the uncertainty of the measurement is the range within which the true discharge can be expected to lie 95 percent of the time (' 95 percent confidence level ').

The uncertainty of a discharge measurement is estimated as the combination of uncertainties in the contributing sources of error. Thus, the relative influence of each contributing source can be assessed to determine whether, with the resources and techniques available, discharges can be measured with sufficient accuracy for the purpose in hand.

11.2 Sources of Error — The sources of error which contribute to uncertainties in weir discharge measurements can be identified by considering representative discharge formulae. For example, from equations 1 and 21, respectively, simplified discharge formulae are, for rectangular weirs,

$$Q_r = J_r \left[C_e \sqrt{g}\, b_e\, h_e^{3/2} \right] \quad \ldots (25)$$

and, for triangular weirs

$$Q_t = J_t \left[C_e \sqrt{g} \tan\frac{\alpha}{2}\, h_e^{5/2} \right] \quad \ldots (26)$$

in which J is a numerical constant, dependent on the form of the weir but not subject to error. Error in g, the acceleration due to gravity, may be neglected. It follows that the only sources of error which need to be considered are:

a) the discharge coefficient C_e;

b) the measured width b or the notch angle α;

c) the measured head h which depends also on the error in the determination of the gauge zero; and

d) the corrective terms k_b and k_h defined in equations 3, 4 and 23.

For those discharge formulae which do not make use of the effective-head and width concept, the k_b and k_h factors are irrelevant, and C_e, b_e and h_e can be replaced by C, b and h.

11.3 Uncertainties Due to Different Kinds of Errors — Errors are classified as random or systematic. Random errors are precision or experimental errors, which deviate from the mean in accordance with the laws of chance. Systematic errors stem from inaccuracies inherent in the equipment and conditions of measurement.

The uncertainty due to random errors can be estimated statistically in terms of the standard deviation. The standard deviation S_y of n measurements of a variable y is given by the equation:

$$Sy = \left[\frac{\sum_{i=1}^{n} (\bar{y} - y)^2}{n - 1} \right]^{1/2} \qquad \ldots(27)$$

in which $\bar{y}$ is the arithmetic means of the measurements. The standard deviation of the mean is:

$$S\bar{y} = \frac{Sy}{\sqrt{n}} \qquad \ldots(28)$$

If the number of measurements is large enough that their deviations from the mean approach a normal distribution, the uncertainty of the mean is equal to $2S\bar{y}$ for the 95 percent confidence level.

It follows that the range in the value of the measured quantity is equal to $\bar{y} \pm 2S\bar{y}$. From equations 27 and 28 it is evident that the range of uncertainty due to random errors can be reduced by increasing the number of measurements.

Because systematic errors are caused by inaccuracies attributable to the equipment and to conditions of measurement, the uncertainty due to systematic errors cannot be reduced by increasing the number of measurements. The uncertainty due to systematic errors shall be estimated subjectively on the basis of knowledge of the equipment and techniques involved.

11.4 Errors in Recommended Coefficients — Values of C_e, C, k_b and k_h used in discharge formulae given in this standard are based on experiments made under different conditions, all believed to satisfy the specifications for standard weir installation and use. The estimated errors in these quantities are based on an assessment of the experiments and a comparison of the results obtained from the recommended formulae. Thus, the errors in C_e, C, k_b and k_h are essentially systematic errors.

Recommended values of the uncertainty in C_e and C to be used under various conditions of measurement are given in **9.8** and **10.7** for

rectangular and triangular weirs, respectively. In general, the coefficient of discharge is subject to greater uncertainty than other sources of systematic error.

For all applications covered by this standard the uncertainties in k_b and k_h can be taken to be 0·3 mm. The influence of both factors on the uncertainty in measured discharge is insignificant except at small values of b and h.

11.5 Errors in Quantities Measured by the User — Quantities measured by the user include b, h, and α. Both random and systematic errors occur in this category. Measurements of b and α, for example, involve measurements of fixed dimensions and distances, and errors depend on the equipment and methods used. Consideration of the conditions of measurement enables the user to estimate the uncertainty in these quantities. Measurements of h depends not only on equipment and technique but also on the fluctuation of water level (for example, in a stilling well or a manometer). Thus, the uncertainty in h depends in part on the random uncertainty in the mean of numerous measurements, and it is estimated as the square root of the sum of the squares of the separate uncertainties.

When the uncertainty of a systematic error can be assessed experimentally, the value of the uncertainty should be calculated by the method described in **11.3** for random errors. When the uncertainty shall be estimated from a single measurement subject to systematic error, the uncertainty should be calculated as one half the range within which the error is estimated to lie.

11.6 Combination of Uncertainties — In **11.4** and **11.5**, systematic and random errors have been distinguished separately. However, because the sign of the systematic errors is not known and because the two types of errors are inextricably linked, they are all treated as random errors when combination of uncertainties is considered.

The following method of calculation should be used to combine the uncertainties which contribute to the overall uncertainty in weir discharge measurements (at 95 percent confidence level). For rectangular weirs, from the simplified equations of discharge given in **11.2**,

$$X_{Q_r} = \pm\sqrt{X^2_{C_e} + X^2_{b_e} + 1{\cdot}5^2 X^2_{h_e}} \qquad \ldots(29)$$

and, for triangular weirs,

$$X_{Q_t} = \pm\sqrt{X^2_{C_e} + X^2_{\tan \alpha/2} + 2{\cdot}5^2 X^2_{he}} \qquad \ldots(30)$$

in which

X = uncertainty, expressed as a percentage,

X_Q = uncertainty in the calculated value of the discharge,

X_{C_e} = uncertainty in the coefficient of discharge,

X_{b_e} = uncertainty in the effective width for a rectangular weir,

$X_{\tan\alpha/2}$ = uncertainty in the notch angle for a triangular weir, and

X_{h_e} = uncertainty in the effective head.

The uncertainty in b_e is given by:

$$X_{b_e} = \pm \frac{100\sqrt{e^2_b + e^2_{k_b}}}{b} \quad \ldots(31)$$

in which

e_b = uncertainty in the measured width, and

e_{k_b} = uncertainty in the width correction factor.

The uncertainty in h_e is given by:

$$X_{h_e} = \pm \frac{100\sqrt{e^2_h + e^2_{h_o} + e^2_{k_h} + (2S_{\bar{h}})^2}}{h} \quad \ldots(32)$$

in which

e_h = uncertainty in the measured head,

e_{h_o} = uncertainty in the gauge zero,

e_{k_h} = uncertainty in the head correction factor, and

$2S_{\bar{h}}$ = uncertainty in the mean of n readings of the head.

Calculation of the uncertainty in tan $\alpha/2$ will depend on the method of measurement used. For example, tan $\alpha/2$ could be determined as the quotient of one-half the top width b_t and the vertical height of the notch h_t. With associated errors e_{b_t} and e_{h_t} in the measurement of b_t and h_t, the uncer-ainty in tan $\alpha/2$ would be,

$$X_{\tan\alpha/2} = \pm\, 100\sqrt{\left(\frac{e_{h_t}}{h_t}\right)^2 + \left(\frac{e_{b_t}}{b_t}\right)^2} \quad \ldots(33)$$

For those discharge formulae which do not involve the effective-head and width concepts e_{k_h} and e_{k_b} should be taken to be zero in the preceding equations.

The uncertainty of the discharge measurements is not single valued for a given installation, but will vary with the rate of flow. It is usually desirable, therefore, to consider the uncertainty at several discharges covering the required range of measurement.

12. EXAMPLES OF UNCERTAINTY CALCULATIONS

12.1 Rectangular Weir — The following example illustrates the calculation of the overall uncertainty in a discharge measurement made with a rectangular weir under the following conditions: $b = 0{\cdot}30$ m; $p = 0{\cdot}20$ m; $h = 0{\cdot}080$ m; standard deviation based on 10 successive head readings = 0·05 mm.

12.1.1 *Uncertainties Given in this Calculation*

Coefficient of discharge $X_{C_e} = \pm\ 1{\cdot}5$ percent
Head correction $e_{k_h} = \pm\ 0{\cdot}30$ mm
Width correction $e_{k_b} = \pm\ 0{\cdot}30$ mm

12.1.2 *Uncertainties Estimated by the User*

Head $e_h = \pm\ 0{\cdot}20$ mm
Head-gauge zero $e_{h_0} = \pm\ 0{\cdot}30$ mm
Standard deviation (head) $S_h = 0{\cdot}05$ mm
Width $e_b = \pm\ 0{\cdot}50$ mm

12.1.3 *Calculated Uncertainties*

The uncertainty in b_e is, from equation 31,

$$X_{b_e} = \pm\ \frac{100\sqrt{0{\cdot}50^2 + 0{\cdot}30^2}}{300} = \pm\ 0{\cdot}19 \text{ percent}$$

The uncertainty in h_e is, from equation 32,

$$X_{h_e} = \pm\ \frac{100\sqrt{0{\cdot}20^2 + 0{\cdot}30^2 + 0{\cdot}30^2 + (2 \times 0{\cdot}05)^2}}{80}$$

$$= \pm\ 0{\cdot}6 \text{ percent}$$

and the overall uncertainty in the weir discharge is, from equation 29 (for 95 percent confidence level),

$$X_{Q_r} = \pm\ \sqrt{1{\cdot}50^2 + 0{\cdot}19^2 + 2{\cdot}25 \times 0{\cdot}6^2} = \pm\ 1{\cdot}76 \text{ percent}$$

12.2 Triangular-Notch Weir — The following example illustrates the calculation of the overall uncertainty in a discharge measurement made with a triangular-notch weir under the following conditions: $\alpha = 90°$; $p = 0{\cdot}30$ m; $h = 0{\cdot}121$ m; standard deviation based on 15 successive head readings = 0·03 mm. The notch angle is measured in terms of the top width, b_t, and the vertical height, h_t, of the notch.

12.2.1 *Uncertainties Given in this Calculation*

Coefficient of discharge $X_{C_e} = \pm 1{\cdot}0$ percent
Head correction $X_{k_h} = \pm 0{\cdot}30$ mm

12.2.2 *Uncertainties Estimated by the User*

Head $e_h = \pm 0{\cdot}10$ mm
Head-gauge zero $e_{h_o} = \pm 0{\cdot}10$ mm
Standard deviation (head) $S_{\bar{h}} = 0{\cdot}03$ mm
Top width of notch $e_{b_t} = \pm 0{\cdot}50$ mm
Height of notch $e_{h_t} = \pm 1{\cdot}0$ mm

12.2.3 *Calculated Uncertainties*

The uncertainty in tan $\alpha/2$ is, from equation 33,

$$X_{\tan \alpha/2} = \pm 100 \sqrt{\left(\frac{1{\cdot}0}{220}\right)^2 + \left(\frac{0{\cdot}5}{440}\right)^2} = \pm 0{\cdot}47 \text{ percent}$$

The uncertainty in h_e is, from equation 32,

$$X_{h_e} = \pm \frac{100\sqrt{0{\cdot}10^2 + 0{\cdot}10^2 + 0{\cdot}30^2 + (2 \times 0{\cdot}03)^2}}{121}$$

$$= \pm 0{\cdot}28 \text{ percent}$$

and the overall uncertainty in the weir discharge is, from equation 30 (for 95 percent confidence level),

$$X_{Q_t} = \pm \sqrt{1{\cdot}0^2 + 0{\cdot}47^2 + 6{\cdot}25 \times 0{\cdot}28^2} = \pm 1{\cdot}31 \text{ percent}$$

TABLE 1 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan\frac{\alpha}{2} = 1$ ($\alpha = 90°$)

(*Clause* 10.6)

$Q = 2.362\,5\ C_e\ h^{5/2}$
($g = 9.806\,6\ m/s^2$)

Head h	Coefficient C_e	Discharge Q	Head h	Coefficient C_e	Discharge Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·060	0·603 2	0·012 57	0·095	0·592 7	0·038 95
0·061	0·602 8	0·013 09	0·096	0·592 5	0·039 97
0·062	0·602 3	0·013 62	0·097	0·592 3	0·041 01
0·063	0·601 9	0·014 17	0·098	0·592 1	0·042 06
0·064	0·601 5	0·014 73	0·099	0·591 9	0·043 12
0·065	0·601 2	0·015 30			
0·066	0·600 8	0·015 88	0·100	0·591 7	0·044 20
0·067	0·600 5	0·016 48	0·101	0·591 4	0·045 30
0·068	0·600 1	0·017 10	0·102	0·591 2	0·046 41
0·069	0·599 8	0·017 72	0·103	0·591 0	0·047 54
			0·104	0·590 8	0·048 69
0·070	0·599 4	0·018 36	0·105	0·590 6	0·049 85
0·071	0·599 0	0·019 01	0·106	0·590 4	0·051 03
0·072	0·598 7	0·019 67	0·107	0·590 2	0·052 22
0·073	0·598 3	0·020 35	0·108	0·590 1	0·053 44
0·074	0·598 0	0·021 05	0·109	0·589 9	0·054 67
0·075	0·597 8	0·021 76			
0·076	0·597 5	0·022 48	0·110	0·589 8	0·055 92
0·077	0·597 3	0·023 22	0·111	0·589 7	0·057 19
0·078	0·597 0	0·023 97	0·112	0·589 6	0·058 47
0·079	0·596 7	0·024 73	0·113	0·589 4	0·059 77
			0·114	0·589 2	0·061 08
0·080	0·596 4	0·025 51	0·115	0·589 1	0·062 42
0·081	0·596 1	0·026 30	0·116	0·589 0	0·063 77
0·082	0·595 8	0·027 10	0·117	0·588 9	0·065 14
0·083	0·595 5	0·027 92	0·118	0·588 8	0·066 53
0·084	0·595 3	0·028 76	0·119	0·588 6	0·067 93
0·085	0·595 0	0·029 61			
0·086	0·594 8	0·030 48	0·120	0·588 5	0·069 35
0·087	0·594 5	0·031 36	0·121	0·588 3	0·070 79
0·088	0·594 2	0·032 25	0·122	0·588 2	0·072 24
0·089	0·594 0	0·033 16	0·123	0·588 1	0·073 72
			0·124	0·588 0	0·075 22
0·090	0·593 7	0·034 09	0·125	0·588 0	0·076 73
0·091	0·593 5	0·035 03	0·126	0·587 9	0·078 27
0·092	0·593 3	0·035 98	0·127	0·587 8	0·079 82
0·093	0·593 1	0·036 96	0·128	0·587 7	0·081 39
0·094	0·592 9	0·037 95	0·129	0·587 6	0·082 98

(*Continued*)

TABLE 1 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH TAN $\frac{\alpha}{2}$ = 1 (α = 90°) — *Contd*

Head h	Coefficient C_e	Discharge Q	Head h	Coefficient C_e	Discharge Q
m		m³/s × 10⁻¹	m		m³/s × 10⁻¹
0·130	0·587 6	0·084 58	0·170	0·585 3	0·164 77
0·131	0·587 5	0·086 21	0·171	0·585 3	0·167 19
0·132	0·587 4	0·087 85	0·172	0·585 2	0·169 64
0·133	0·587 3	0·089 51	0·173	0·585 2	0·172 10
0·134	0·587 2	0·091 19	0·174	0·585 1	0·174 59
0·135	0·587 2	0·092 89	0·175	0·585 1	0·177 09
0·136	0·587 1	0·094 61	0·176	0·585 1	0·179 63
0·137	0·587 0	0·096 34	0·177	0·585 1	0·182 19
0·138	0·586 9	0·098 10	0·178	0·585 1	0·184 78
0·139	0·586 9	0·099 87	0·179	0·585 1	0·187 38
0·140	0·586 8	0·101 67	0·180	0·585 1	0·190 01
0·141	0·586 7	0·103 48	0·181	0·585 1	0·192 65
0·142	0·586 7	0·105 32	0·182	0·585 0	0·195 31
0·143	0·586 6	0·107 17	0·183	0·585 0	0·198 00
0·144	0·586 6	0·109 04	0·184	0·585 0	0·200 71
0·145	0·586 5	0·110 93	0·185	0·585 0	0·203 45
0·146	0·586 4	0·112 84	0·186	0·585 0	0·206 21
0·147	0·586 3	0·114 76	0·187	0·585 0	0·208 99
0·148	0·586 2	0·116 71	0·188	0·585 0	0·211 80
0·149	0·586 2	0·118 67	0·189	0·585 0	0·214 63
0·150	0·586 1	0·120 66	0·190	0·585 0	0·217 48
0·151	0·586 1	0·122 67	0·191	0·585 0	0·220 34
0·152	0·586 0	0·124 71	0·192	0·584 9	0·223 22
0·153	0·586 0	0·126 76	0·193	0·584 9	0·226 12
0·154	0·585 9	0·128 83	0·194	0·584 9	0·229 06
0·155	0·585 9	0·130 93	0·195	0·584 9	0·232 03
0·156	0·585 9	0·133 04	0·196	0·584 9	0·235 01
0·157	0·585 8	0·135 17	0·197	0·584 9	0·238 02
0·158	0·585 8	0·137 32	0·198	0·584 9	0·241 06
0·159	0·585 7	0·139 50	0·199	0·584 9	0·244 11
0·160	0·585 7	0·141 69	0·200	0·584 9	0·247 19
0·161	0·585 7	0·143 91	0·201	0·584 9	0·250 28
0·162	0·585 6	0·146 14	0·202	0·584 8	0·253 39
0·163	0·585 6	0·148 40	0·203	0·584 8	0·256 52
0·164	0·585 5	0·150 67	0·204	0·584 8	0·259 69
0·165	0·585 5	0·152 97	0·205	0·584 8	0·262 88
0·166	0·585 5	0·155 29	0·206	0·584 8	0·266 10
0·167	0·585 4	0·157 63	0·207	0·584 8	0·269 34
0·168	0·585 4	0·159 99	0·208	0·584 8	0·272 61
0·169	0·585 3	0·162 37	0·209	0·584 8	0·275 90

(*Continued*)

TABLE 1 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH TAN $\frac{\alpha}{2} = 1$ ($\alpha = 90°$) — *Contd*

Head h	Coefficient C_e	Discharge Q	Head h	Coefficient C_e	Discharge Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·210	0·584 8	0·279 21	0·250	0·584 6	0·431 60
0·211	0·584 8	0·282 54	0·251	0·584 6	0·435 93
0·212	0·584 8	0·285 88	0·252	0·584 6	0·440 28
0·213	0·584 7	0·289 24	0·253	0·584 6	0·444 66
0·214	0·584 7	0·292 64	0·254	0·584 6	0·449 07
0·215	0·584 7	0·296 07	0·255	0·584 6	0·453 50
0·216	0·584 7	0·299 53	0·256	0·584 6	0·457 96
0·217	0·584 7	0·303 01	0·257	0·584 6	0·462 45
0·218	0·584 7	0·306 51	0·258	0·584 6	0·466 96
0·219	0·584 7	0·310 04	0·259	0·584 6	0·471 50
0·220	0·584 7	0·313 59	0·260	0·584 6	0·476 06
0·221	0·584 7	0·317 17	0·261	0·584 6	0·480 65
0·222	0·584 7	0·320 77	0·262	0·584 6	0·485 27
0·223	0·584 7	0·324 39	0·263	0·584 6	0·489 91
0·224	0·584 7	0·328 03	0·264	0·584 6	0·494 58
0·225	0·584 6	0·331 68	0·265	0·584 6	0·499 28
0·226	0·584 6	0·335 35	0·266	0·584 6	0·504 00
0·227	0·584 6	0·339 07	0·267	0·584 6	0·508 76
0·228	0·584 6	0·342 82	0·268	0·584 6	0·513 53
0·229	0·584 6	0·346 59	0·269	0·584 6	0·518 34
0·230	0·584 6	0·350 39	0·270	0·584 6	0·523 17
0·231	0·584 6	0·354 21	0·271	0·584 6	0·528 02
0·232	0·584 6	0·358 06	0·272	0·584 6	0·532 91
0·233	0·584 6	0·361 93	0·273	0·584 6	0·537 82
0·234	0·584 6	0·365 82	0·274	0·584 6	0·542 76
0·235	0·584 6	0·369 74	0·275	0·584 6	0·547 72
0·236	0·584 6	0·373 69	0·276	0·584 6	0·552 72
0·237	0·584 6	0·377 66	0·277	0·584 6	0·557 74
0·238	0·584 6	0·381 66	0·278	0·584 6	0·562 82
0·239	0·584 6	0·385 68	0·279	0·584 7	0·567 94
0·240	0·584 6	0·389 73	0·280	0·584 7	0·573 06
0·241	0·584 6	0·393 80	0·281	0·584 7	0·578 19
0·242	0·584 6	0·397 90	0·282	0·584 7	0·583 35
0·243	0·584 6	0·402 02	0·283	0·584 7	0·588 53
0·244	0·584 6	0·406 17	0·284	0·584 7	0·593 75
0·245	0·584 6	0·410 34	0 285	0·584 7	0·598 99
0·246	0·584 6	0·414 54	0·286	0·584 7	0·604 25
0·247	0·584 6	0·418 77	0·287	0·584 7	0·609 55
0·248	0·584 6	0·423 02	0 288	0·584 7	0·614 87
0·249	0·584 6	0·427 30	0·289	0·584 7	0·620 23

(*Continued*)

TABLE 1 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan\frac{\alpha}{2} = 1$ ($\alpha = 90°$) — *Contd*

Head h	Coefficient C_e	Discharge Q	Head h	Coefficient C_e	Discharge Q
m		m³/s × 10⁻¹	m		m³/s × 10⁻¹
0·290	0·584 7	0·625 60	0·330	0·585 0	0·864 59
0·291	0·584 7	0·631 01	0·331	0·585 0	0·871 16
0·292	0·584 7	0·636 45	0·332	0·585 0	0·877 75
0·293	0·584 7	0·641 95	0·333	0·585 0	0·884 38
0·294	0·584 8	0·647 48	0·334	0·585 0	0·891 03
0·295	0·584 8	0·653 03	0·335	0·585 0	0·897 72
0·296	0·584 8	0·658 58	0·336	0·585 0	0·904 48
0·297	0·584 8	0·664 16	0·337	0·585 1	0·911 28
0·298	0·584 8	0·669 76	0·338	0·585 1	0·918 11
0·299	0·584 8	0·675 39	0·339	0·585 1	0·924 91
0·300	0·584 8	0·681 06	0·340	0·585 1	0·931 75
0·301	0·584 8	0·686 75	0·341	0·585 1	0·938 62
0·302	0·584 8	0·692 46	0·342	0·585 1	0·945 51
0·303	0·584 8	0·698 21	0·343	0·585 1	0·952 44
0·304	0·584 8	0·703 98	0·344	0·585 1	0·959 40
0·305	0·584 8	0·709 80	0·345	0·585 1	0·966 38
0·306	0·584 8	0·715 68	0·346	0·585 1	0·973 40
0·307	0·584 9	0·721 59	0·347	0·585 1	0·980 45
0·308	0·584 9	0·727 50	0·348	0·585 1	0·987 53
0·309	0·584 9	0·733 41	0·349	0·585 1	0·994 71
0·310	0·584 9	0·739 36	0·350	0·585 2	1·001 92
0·311	0·584 9	0·745 34	0·351	0·585 2	1·009 12
0·312	0·584 9	0·751 35	0·352	0·585 2	1·016 33
0·313	0·584 9	0·757 38	0·353	0·585 2	1·023 56
0·314	0·584 9	0·763 44	0·354	0·585 2	1·030 82
0·315	0·584 9	0·769 54	0·355	0·585 2	1·038 12
0·316	0·584 9	0·775 66	0·356	0·585 2	1·045 45
0·317	0·584 9	0·781 81	0·357	0·585 2	1·052 80
0·318	0·584 9	0·788 02	0·358	0·585 2	1·060 19
0·319	0·585 0	0·794 28	0·359	0·585 2	1·067 67
0·320	0·585 0	0·800 57	0·360	0·585 3	1·075 19
0·321	0·585 0	0·806 85	0·361	0·585 3	1·082 73
0·322	0·585 0	0·813 14	0·362	0·585 3	1·090 24
0·323	0·585 0	0·819 47	0·363	0·585 3	1·097 78
0·324	0·585 0	0·825 83	0·364	0·585 3	1·105 36
0·325	0·585 0	0·832 22	0·365	0·585 3	1·112 97
0·326	0·585 0	0·838 63	0·366	0·585 3	1·120 63
0·327	0·585 0	0·845 08	0·367	0·585 3	1·128 37
0·328	0·585 0	0·851 55	0·368	0·585 4	1·136 15
0·329	0·585 0	0·858 06	0·369	0·585 4	1·143 91

(*Continued*)

TABLE 1 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH TAN $\frac{\alpha}{2} = 1$ ($\alpha = 90°$) — *Contd*

HEAD h	COEFFICIENT C_e	DISCHARGE Q	HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		$m^3/s \times 10^{-1}$	m		$m^3/ \times 10^{-1}$
0·370	0·585 4	1·151 67	0·377	0·585 5	1·207 12
0·371	0·585 4	1·159 47	0·378	0·585 5	1·215 15
0·372	0·585 4	1·167 30	0·379	0·585 5	1·223 20
0·373	0·585 4	1·175 16	0·380	0·585 5	1·231 28
0·374	0·585 4	1·183 10	0·381	0·585 5	1·239 40
0·375	0·585 5	1·191 11			
0·376	0·585 5	1·199 14			

TABLE 2 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH TAN $\frac{\alpha}{2} = 1/2$ ($\alpha = 53°8'$)

(*Clause* 10·6)

$$Q = 1{\cdot}181\,25\ C_e\ h^{5/2}$$
$$(g = 9{\cdot}806\,6\ m/s^2)$$

HEAD h	COEFFICIENT C_e	DISCHARGE Q	HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·060	0·611 4	0·006 37	0·080	0·606 0	0·012 96
0·061	0·611 1	0·006 63	0·081	0·605 8	0·013 36
0·062	0·610 8	0·006 91	0·082	0·605 6	0·013 77
0·063	0·610 5	0·007 18	0·083	0·605 4	0·014 19
0·064	0·610 1	0·007 47	0·084	0·605 2	0·014 62
0·065	0·609 8	0·007 76	0·085	0·605 0	0·015 05
0·066	0·609 5	0·008 06	0·086	0·604 8	0·015 49
0·067	0·609 2	0·008 36	0·087	0·604 6	0·015 94
0·068	0·609 0	0·008 67	0·088	0·604 4	0·016 40
0·069	0·608 7	0·008 99	0·089	0·604 2	0·016 86
0·070	0·608 4	0·009 32	0·090	0·604 0	0·017 34
0·071	0·608 1	0·009 65	0·091	0·603 8	0·017 82
0·072	0·607 9	0·009 99	0·092	0·603 6	0·018 30
0·073	0·607 6	0·010 33	0·093	0·603 4	0·018 80
0·074	0·607 3	0·010 69	0·094	0·603 2	0·019 30
0·075	0·607 1	0·011 05	0·095	0·603 0	0·019 81
0·076	0·606 8	0·011 41	0·096	0·602 8	0·020 33
0·077	0·606 6	0·011 79	0·097	0·602 6	0·020 86
0·078	0·606 4	0·012 17	0·098	0·602 4	0·021 39
0·079	0·606 1	0·012 56	0·099	0·602 2	0·021 94

(*Continued*)

TABLE 2 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan\frac{\alpha}{2} = 1/2$ ($\alpha = 53°8'$) — *Contd*

Head h	Coefficient C_e	Discharge Q	Head h	Coefficient C_e	Discharge Q
m		m³/s × 10⁻¹	m		m³/s × 10⁻¹
0·100	0·602 1	0·022 49	0·140	0·596 4	0·051 66
0·101	0·601 9	0·023 05	0·141	0·596 2	0·052 58
0·102	0·601 7	0·023 62	0·142	0·596 1	0·053 51
0·103	0·601 6	0·024 20	0·143	0·596 0	0·054 44
0·104	0·601 4	0·024 78	0·144	0·596 0	0·055 39
0·105	0·601 3	0·025 37	0·145	0·595 9	0·056 35
0·106	0·601 1	0·025 98	0·146	0·595 8	0·057 32
0·107	0·600 9	0·026 59	0·147	0·595 7	0·058 30
0·108	0·600 8	0·027 20	0·148	0·595 6	0·059 29
0·109	0·600 6	0·027 83	0·149	0·595 6	0·060 29
0·110	0·600 5	0·028 47	0·150	0·595 5	0·061 30
0·111	0·600 3	0·029 11	0·151	0·595 4	0·062 31
0·112	0·600 2	0·029 76	0·152	0·595 2	0·063 34
0·113	0·600 0	0·030 42	0·153	0·595 2	0·064 37
0·114	0·599 8	0·031 09	0·154	0·595 1	0·065 42
0·115	0·599 7	0·031 77	0·155	0·595 0	0·066 48
0·116	0·599 5	0·032 46	0·156	0·594 9	0·067 55
0·117	0·599 4	0·033 15	0·157	0·594 8	0·068 63
0·118	0·599 2	0·033 86	0·158	0·594 8	0·069 71
0·119	0·599 1	0·034 57	0·159	0·594 7	0·070 81
0·120	0·598 9	0·035 29	0·160	0·594 6	0·071 92
0·121	0·598 8	0·036 02	0·161	0·594 5	0·073 04
0·122	0·598 7	0·036 77	0·162	0·594 4	0·074 17
0·123	0·598 5	0·037 51	0·163	0·594 4	0·075 31
0·124	0·598 4	0·038 27	0·164	0·594 3	0·076 46
0·125	0·598 2	0·039 04	0·165	0·594 2	0·077 62
0·126	0·598 1	0·039 82	0·166	0·594 1	0·078 79
0·127	0·598 0	0·040 60	0·167	0·594 1	0·079 98
0·128	0·597 9	0·041 40	0·168	0·594 0	0·081 17
0·129	0·597 8	0·042 20	0·169	0·593 9	0·082 37
0·130	0·597 6	0·043 02	0·170	0·593 8	0·083 58
0·131	0·597 5	0·043 84	0·171	0·593 7	0·084 81
0·132	0·597 3	0·044 67	0·172	0·593 7	0·086 04
0·133	0·597 2	0·045 51	0·173	0·593 6	0·087 28
0·134	0·597 1	0·046 36	0·174	0·593 5	0·088 54
0·135	0·597 0	0·047 22	0·175	0·593 4	0·089 80
0·136	0·596 8	0·048 09	0·176	0·593 3	0·091 08
0·137	0·596 7	0·048 97	0·177	0·593 3	0·092 37
0·138	0·596 6	0·049 86	0·178	0·593 2	0·093 67
0·139	0·596 5	0·050 75	0·179	0·593 1	0·094 97

(Continued)

TABLE 2 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH TAN $\frac{\alpha}{2}$ = 1/2 (α = 53°8′) — *Contd*

HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		$m^3/s \times 10^{-1}$
0·180	0·593 0	0·096 29
0·181	0·592 9	0 097 62
0·182	0·592 9	0·098 96
0·183	0·592 8	0·100 32
0·184	0·592 7	0·101 68
0·185	0·592 6	0·103 05
0·186	0 592 6	0·104 44
0·187	0·592 5	0·105 84
0·188	0·592 5	0·107 26
0·189	0·592 4	0·108 67
0·190	0·592 3	0·110 10
0·191	0·592 3	0·111 55
0·192	0·592 2	0·113 00
0·193	0·592 2	0·114 47
0·194	0·592 1	0·115 95
0·195	0·592 0	0·117 43
0·196	0·592 0	0·118 93
0·197	0·591 9	0·120 44
0·198	0·591 9	0·121 97
0·199	0·591 9	0·123 51
0·200	0·591 8	0·125 06
0·201	0·591 8	0·126 62
0·202	0·591 7	0·128 19
0·203	0·591 7	0·129 77
0·204	0·591 6	0·131 36
0·205	0·591 6	0·132 96
0·206	0·591 5	0·134 57
0·207	0·591 5	0·136 20
0·208	0·591 4	0·137 84
0·209	0·591 3	0·139 49
0·210	0·591 3	0·141 15
0·211	0·591 2	0·142 82
0·212	0·591 2	0·144 50
0·213	0·591 1	0·146 20
0·214	0·591 1	0·147 92
0·215	0·591 0	0·149 64
0·216	0·591 0	0·151 38
0·217	0·591 0	0·153 13
0·218	0·500 9	0·154 89
0·219	0·500 9	0·156 66
0·220	0·590 8	0·158 44
0·221	0·590 8	0·160 24
0·222	0·590 8	0·162 04
0·223	0·590 7	0·163 86
0·224	0·590 7	0·165 70
0·225	0·590 6	0·167 54
0·226	0·590 6	0·169 40
0·227	0·590 6	0·171 27
0·228	0·590 5	0·173 15
0·229	0·590 5	0·175 04
0·230	0·590 4	0·176 95
0·231	0·590 4	0·178 86
0·232	0·590 4	0·180 79
0·233	0·590 3	0·182 74
0·234	0·590 3	0·184 69
0·235	0·590 2	0·186 66
0·236	0·590 2	0·188 64
0·237	0·590 2	0·190 63
0·238	0·590 1	0 192 63
0·239	0·590 1	0·194 65
0·240	0·590 1	0·196 68
0·241	0·590 0	0·198 72
0·242	0·590 0	0·200 79
0·243	0·590 0	0·202 87
0·244	0·589 9	0·204 96
0·245	0·589 9	0·207 05
0·246	0·589 8	0·209 16
0·247	0·589 8	0·211 27
0·248	0·589 8	0·213 40
0·249	0·589 8	0·215 55
0·250	0·589 8	0·217 72
0·251	0·589 8	0·219 90
0·252	0·589 8	0·222 09
0·253	0·589 7	0·224 29
0·254	0·589 7	0·226 49
0·255	0·589 7	0·228 73
0·256	0·589 7	0·230 98
0·257	0·589 7	0·233 23
0·258	0·589 6	0·235 49
0·259	0·589 6	0·237 77

(*Continued*)

TABLE 2 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH TAN $\frac{\alpha}{2}$ = 1/2 (α = 53°8′) — *Contd*

HEAD h	COEFFICIENT C_e	DISCHARGE Q	HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·260	0·589 6	0·240 05	0·300	0·588 5	0·342 68
0·261	0·589 5	0·242 35	0·301	0·588 4	0·345 52
0·262	0·589 5	0·244 66	0·302	0·588 4	0·348 37
0·263	0·589 4	0·246 99	0·303	0·588 4	0·351 24
0·264	0·589 4	0·249 33	0·304	0·588 3	0·354 12
0·265	0·589 4	0·251 68	0·305	0·588 3	0·357 02
0·266	0·589 3	0·254 04	0·306	0·588 3	0·359 95
0·267	0·589 3	0·256 42	0·307	0·588 3	0·362 90
0·268	0·589 2	0·258 81	0·308	0·588 3	0·365 85
0·269	0·589 2	0·261 21	0·309	0·588 2	0·368 80
0·270	0·589 2	0·263 63	0·310	0·588 2	0·371 77
0·271	0·589 1	0·266 06	0·311	0·588 2	0·374 77
0·272	0·589 1	0·268 51	0·312	0·588 2	0·377 79
0·273	0·589 1	0·270 98	0·313	0·588 2	0·380 81
0·274	0·589 1	0·273 47	0·314	0·588 1	0·383 84
0·275	0·589 1	0·275 96	0·315	0·588 1	0·386 87
0·276	0·589 0	0·278 45	0·316	0·588 1	0·389 95
0·277	0·589 0	0·280 97	0·317	0·588 1	0·393 04
0·278	0·589 0	0·283 51	0·318	0·588 1	0·396 15
0·279	0·589 0	0·286 07	0·319	0·588 1	0·399 27
0·280	0·589 0	0·288 63	0·320	0·588 1	0·402 41
0·281	0·588 9	0·291 19	0·321	0·588 1	0·405 53
0·282	0·588 9	0·293 77	0·322	0·588 0	0·408 67
0·283	0·588 9	0·296 38	0·323	0·588 0	0·411 84
0·284	0·588 9	0·299 01	0·324	0·588 0	0·415 03
0·285	0·588 9	0·301 63	0·325	0·588 0	0·418 24
0·286	0·588 8	0·304 27	0·326	0·588 0	0·421 47
0·287	0·588 8	0·306 91	0·327	0·588 0	0·424 71
0·288	0·588 8	0·309 59	0·328	0·588 0	0·427 96
0·289	0·588 8	0·312 29	0·329	0·588 0	0·431 23
0·290	0·588 8	0·314 99	0·330	0·588 0	0·434 51
0·291	0·588 7	0·317 69	0·331	0·588 0	0·437 79
0·292	0·588 7	0·320 40	0·332	0·587 9	0·441 07
0·293	0·588 7	0·323 15	0·333	0·587 9	0·444 38
0·294	0·588 7	0·325 91	0·334	0·587 9	0·447 73
0·295	0·588 7	0·328 69	0·335	0·587 9	0·451 08
0·296	0·588 6	0·331 46	0·336	0·587 9	0·454 46
0·297	0·588 6	0·334 24	0·337	0·587 9	0·457 85
0·298	0·588 6	0·337 04	0·338	0·587 9	0·461 25
0·299	0·588 5	0·339 85	0·339	0·587 9	0·464 67

(*Continued*)

TABLE 2 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan\frac{\alpha}{2} = 1/2$ ($\alpha = 53°8'$) — *Contd*

HEAD h	COEFFICIENT C_e	DISCHARGE Q	HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·340	0·587 9	0·468 10	0·360	0·587 5	0·539 67
0·341	0·587 9	0·471 53	0·361	0·587 5	0·543 40
0·342	0·587 8	0·474 97	0·362	0·587 5	0·547 17
0·343	0·587 8	0·478 42	0·363	0·587 5	0·550 96
0·344	0·587 8	0·481 91	0·364	0·587 5	0·554 73
0·345	0·587 8	0·485 42	0·365	0·587 4	0·558 51
0·346	0·587 8	0·488 95	0·366	0·587 4	0·562 31
0·347	0·587 8	0·492 49	0·367	0·587 4	0·566 16
0·348	0·587 8	0·496 04	0·368	0·587 4	0·570 03
0·349	0·587 8	0·499 58	0·369	0·587 4	0·573 91
0·350	0·587 7	0·503 13	0·370	0·587 4	0·577 80
0·351	0·587 7	0·506 72	0·371	0·587 4	0·581 71
0·352	0·587 7	0·510 33	0·372	0·587 4	0·585 60
0·353	0·587 7	0·513 97	0·373	0·587 3	0·589 50
0·354	0·587 7	0·517 58	0·374	0·587 3	0·593 45
0·355	0·587 6	0·521 21	0·375	0·587 3	0·597 42
0·356	0·587 6	0·524 87	0·376	0·587 3	0·601 41
0·357	0·587 6	0·528 56	0·377	0·587 3	0·605 42
0·358	0·587 6	0·532 27	0·378	0·587 3	0·609 44
0·359	0·587 6	0·535 96	0·379	0·587 3	0·613 46
			0·380	0·587 2	0·617 47
			0·381	0·587 2	0·621 50

TABLE 3 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan\frac{\alpha}{2} = 1/4$ ($\alpha = 28°4'$)

(*Clause* 10.6)

$$Q = 0{\cdot}590\,625\ C_e\ h^{5/2}$$
$$(g = 9{\cdot}806\,6\ m/s^2)$$

HEAD h	COEFFICIENT C_e	DISCHARGE Q	HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·060	0·641 7	0·003 34	0·070	0·635 2	0·004 86
0·061	0·641 0	0·003 48	0·071	0·634 6	0·005 03
0·062	0·640 3	0·003 62	0·072	0·634 0	0·005 21
0·063	0·639 6	0·003 76	0·073	0·633 5	0·005 39
0·064	0·639 0	0·003 91	0·074	0·632 9	0·005 57
0·065	0·638 3	0·004 06	0·075	0·632 4	0·005 75
0·066	0·637 6	0·004 21	0·076	0·631 8	0·005 94
0·067	0·637 0	0·004 37	0·077	0·631 3	0·006 13
0·068	0·636 4	0·004 53	0·078	0·630 8	0·006 33
0·069	0·635 8	0·004 70	0·079	0·630 3	0·006 53

(*Continued*)

TABLE 3 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH TAN $\frac{\alpha}{2}$ = 1/4 (α = 28°4′) — *Contd*

HEAD h	COEFFICIENT C_e	DISCHARGE Q	HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		m³/s × 10⁻¹	m		m³/s × 10⁻¹
0·080	0·629 8	0·006 73	0·120	0·616 2	0·018 15
0·081	0·629 3	0·006 94	0·121	0·616 0	0·018 53
0·082	0·628 9	0·007 15	0·122	0·615 8	0·018 91
0·083	0·628 5	0·007 37	0·123	0·615 5	0·019 29
0·084	0·628 0	0·007 59	0·124	0·615 3	0·019 68
0·085	0·627 6	0·007 81	0·125	0·615 1	0·020 07
0·086	0·627 2	0·008 03	0·126	0·614 8	0·020 46
0·087	0·626 7	0·008 26	0·127	0·614 6	0·020 86
0·088	0·626 4	0·008 50	0·128	0·614 4	0·021 27
0·089	0·626 0	0·008 74	0·129	0·614 1	0·021 68
0·090	0·625 6	0·008 98	0·130	0·613 9	0·022 09
0·091	0·625 2	0·009 22	0·131	0·613 7	0·022 51
0·092	0·624 8	0·009 47	0·132	0·613 5	0·022 94
0·093	0·624 4	0·009 73	0·133	0·613 3	0·023 37
0·094	0·624 0	0·009 98	0·134	0·613 1	0·023 80
0·095	0·623 6	0·010 25	0·135	0·612 9	0·024 24
0·096	0·623 3	0·010 51	0·136	0·612 7	0·024 68
0·097	0·622 9	0·010 78	0·137	0·612 5	0·025 13
0·098	0·622 6	0·011 06	0·138	0·612 3	0·025 59
0·099	0·622 2	0·011 33	0·139	0·612 1	0·026 04
0·100	0·621 9	0·011 61	0·140	0·611 9	0·026 51
0·101	0·621 5	0·011 90	0·141	0·611 7	0·026 97
0·102	0·621 2	0·012 19	0·142	0·611 5	0·027 44
0·103	0·620 9	0·012 49	0·143	0·611 3	0·027 92
0·104	0·620 5	0·012 78	0·144	0·611 2	0·028 40
0·105	0·620 2	0·013 09	0·145	0·611 0	0·028 89
0·106	0·619 9	0·013 39	0·146	0·610 8	0·029 38
0·107	0·619 6	0·013 71	0·147	0·610 6	0·029 88
0·108	0·619 3	0·014 02	0·148	0·610 5	0·030 38
0·109	0·619 0	0·014 34	0·149	0·610 3	0·030 89
0·110	0·618 7	0·014 66	0·150	0·610 2	0·031 40
0·111	0·618 4	0·014 99	0·151	0·610 0	0·031 92
0·112	0·618 1	0·015 33	0·152	0.609 9	0·032 45
0·113	0·617 9	0·015 66	0·153	0·609 7	0·032 97
0·114	0·617 6	0·016 01	0·154	0·609 5	0·033 50
0·115	0·617 3	0·016 35	0·155	0·609 3	0·034 04
0·116	0·617 1	0·016 70	0·156	0·609 1	0·034 58
0·117	0·616 9	0·017 06	0·157	0·609 0	0·035 13
0·118	0·616 6	0·017 42	0·158	0·608 8	0·035 68
0·119	0·616 4	0·017 78	0·159	0·608 7	0·036 24

(*Continued*)

TABLE 3 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan\frac{\alpha}{2} = 1/4$ ($\alpha = 28°4'$) — *Contd*

Head h	Coefficient C_e	Discharge Q	Head h	Coefficient C_e	Discharge Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·160	0·608 5	0·036 80	0·200	0·603 8	0·063 79
0·161	0·608 3	0·037 37	0·201	0·603 7	0·064 58
0·162	0·608 2	0·037 94	0·202	0·603 5	0·065 37
0·163	0·608 0	0·038 52	0·203	0·603 4	0·066 17
0·164	0·607 9	0·039 11	0·204	0·603 3	0·066 98
0·165	0·607 7	0·039 69	0·205	0·603 3	0·067 80
0·166	0·607 6	0·040 29	0·206	0·603 2	0·068 62
0·167	0·607 4	0·040 89	0·207	0·603 1	0·069 44
0·168	0·607 3	0·041 49	0·208	0·603 0	0·070 28
0·169	0·607 1	0·042 10	0·209	0·602 9	0·071 11
0·170	0·607 0	0·042 72	0·210	0·602 9	0·071 96
0·171	0·606 9	0·043 34	0·211	0·602 8	0·072 81
0·172	0·606 8	0·043 97	0·212	0·602 7	0·073 66
0·173	0·606 7	0·044 60	0·213	0·602 6	0·074 53
0·174	0·606 5	0·045 24	0·214	0·602 5	0·075 39
0·175	0·606 3	0·045 88	0·215	0·602 5	0·076 27
0·176	0·606 2	0·046 53	0·216	0·602 4	0·077 15
0·177	0·606 1	0·047 18	0·217	0·602 3	0·078 03
0·178	0·606 0	0·047 84	0·218	0·602 2	0·078 93
0·179	0·605 9	0·048 51	0·219	0·602 2	0·079 82
0·180	0·605 7	0·049 18	0·220	0·602 1	0·080 73
0·181	0·605 6	0·049 86	0·221	0·602 0	0·081 64
0·182	0·605 5	0·050 54	0·222	0·601 9	0·082 55
0·183	0·605 4	0·051 22	0·223	0·601 8	0·083 47
0·184	0·605 3	0·051 92	0·224	0·601 8	0·084 41
0·185	0·605 1	0·052 61	0·225	0·601 7	0·085 35
0·186	0·605 1	0·053 32	0·226	0·601 7	0·086 29
0·187	0·605 0	0·054 03	0·227	0·601 6	0·087 24
0·188	0·604 9	0·054 75	0·228	0·601 5	0·088 19
0·189	0·604 8	0·055 47	0·229	0·601 5	0·089 15
0·190	0·604 7	0·056 20	0·230	0·601 4	0·090 11
0·191	0·604 5	0·056 93	0·231	0·601 3	0·091 08
0·192	0·604 4	0·057 66	0·232	0·601 3	0·092 07
0·193	0·604 3	0·058 41	0·233	0·601 2	0·093 06
0·194	0·604 2	0·059 16	0·234	0·601 2	0·094 05
0·195	0·604 1	0·059 92	0·235	0·601 1	0·095 04
0·196	0·604 1	0·060 68	0·236	0·601 0	0·096 05
0·197	0·604 0	0·061 45	0·237	0·601 0	0·097 06
0·198	0·603 9	0·062 22	0·238	0·600 9	0·098 08
0·199	0·603 8	0·063 00	0·239	0·600 9	0·099 10

(Continued)

TABLE 3 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan\frac{\alpha}{2} = 1/4$ (α = 28°4′) — *Contd*

HEAD h	COEFFICIENT C_e	DISCHARGE Q	HEAD h	COEFFICIENT C_e	DISCHARGE Q
m		$m^3/s \times 10^{-1}$	m		$m^3/s \times 10^{-1}$
0·240	0·600 8	0·100 13	0·280	0·598 8	0·146 71
0·241	0·600 7	0·101 16	0·281	0·598 7	0·148 02
0·242	0·600 6	0·102 20	0·282	0·598 7	0·149 33
0·243	0·600 6	0·103 25	0·283	0·598 7	0·150 65
0·244	0·600 5	0·104 30	0·284	0·598 6	0·151 97
0·245	0·600 4	0·105 36	0·285	0·598 6	0·153 30
0·246	0·600 3	0·106 42	0·286	0·598 5	0·154 64
0·247	0·600 3	0·107 50	0·287	0·598 5	0·155 98
0·248	0·600 2	0·108 58	0·288	0·598 5	0·157 34
0·249	0·600 2	0·109 67	0·289	0·598 4	0·158 70
0·250	0·600 2	0·110 77	0·290	0·598 4	0·160 06
0·251	0·600 1	0·111 87	0·291	0·598 3	0·161 43
0·252	0·600 1	0·112 99	0·292	0·598 3	0·162 81
0·253	0·600 0	0·114 10	0·293	0·598 3	0·164 20
0·254	0·600 0	0·115 23	0·294	0·598 2	0·165 59
0·255	0·600 0	0·116 35	0·295	0·598 2	0·166 99
0·256	0·599 9	0·117 49	0·296	0·598 1	0·168 40
0·257	0·599 9	0·118 63	0·297	0·598 1	0·169 82
0·258	0·599 8	0·119 78	0·298	0·598 1	0·171 24
0·259	0·599 8	0·120 94	0·299	0·598 0	0·172 67
0·260	0·599 7	0·122 10	0·300	0·598 0	0·174 10
0·261	0·599 6	0·123 26	0·301	0·597 9	0·175 55
0·262	0·599 6	0·124 43	0·302	0·597 9	0·177 00
0·263	0·599 5	0·125 61	0·303	0·597 9	0·178 45
0·264	0·599 5	0·126 80	0·304	0·597 8	0·179 92
0·265	0·599 5	0·127 99	0·305	0·597 8	0·181 39
0·266	0·599 4	0·129 20	0·306	0·597 8	0·182 87
0·267	0·599 4	0·130 41	0·307	0·597 7	0·184 35
0·268	0·599 3	0·131 62	0·308	0·597 7	0·185 85
0·269	0·599 3	0·132 84	0·309	0·597 6	0·187 35
0·270	0·599 2	0·134 07	0·310	0·597 6	0·188 85
0·271	0·599 2	0·135 29	0·311	0·597 6	0·190 37
0·272	0·599 1	0·136 53	0·312	0·597 5	0·191 89
0·273	0·599 1	0·137 78	0·313	0·597 5	0·193 42
0·274	0·599 0	0·139 03	0·314	0·597 4	0·194 95
0·275	0·599 0	0·140 30	0·315	0·597 4	0·196 50
0·276	0·598 9	0·141 57	0·316	0·597 4	0·198 05
0·277	0·598 9	0·142 84	0·317	0·597 3	0·198 60
0·278	0·598 9	0·144 13	0·318	0·597 3	0·201 17
0·279	0·598 8	0·145 42	0·319	0·597 2	0·202 74

(*Continued*)

TABLE 3 DISCHARGE OF WATER OVER A 'V'-NOTCH WITH $\tan \frac{\alpha}{2} = 1/4$ ($\alpha = 28°4'$) — *Contd*

Head h	Coefficient C_e	Discharge Q
m		$m^3/s \times 10^{-1}$
0·320	0·597 2	0·204 32
0·321	0·597 2	0·205 90
0·322	0·597 1	0·207 50
0·323	0·597 1	0·209 10
0·324	0·597 0	0·210 71
0·325	0·597 0	0·212 32
0·326	0·597 0	0·213 95
0·327	0·596 9	0·215 58
0·328	0·596 9	0·217 21
0·329	0·596 8	0·218 86
0·330	0·596 8	0·220 51
0·331	0·596 8	0·222 17
0·332	0·596 7	0·223 84
0·333	0·596 7	0·225 51
0·334	0·596 7	0·227 19
0·335	0·596 6	0·228 88
0·336	0·596 6	0·230 58
0·337	0·596 5	0·232 28
0·338	0·596 5	0·234 00
0·339	0·596 5	0·235 72
0·340	0·596 4	0·237 44
0·341	0·596 4	0·239 18
0·342	0·596 3	0·240 92
0·343	0·596 3	0·242 67
0·344	0·596 3	0·244 42
0·345	0·596 2	0·246 19
0·346	0·596 2	0·247 96
0·347	0·596 1	0·249 74
0·348	0·596 1	0·251 52
0·349	0·596 1	0·253 32
0·350	0·596 0	0·255 12
0·351	0·596 0	0·256 93
0·352	0·595 9	0·258 75
0·353	0·595 9	0·260 57
0·354	0·595 9	0·262 40
0·355	0·595 8	0·264 24
0·356	0·595 8	0·266 09
0·357	0·595 7	0·267 94
0·358	0·595 7	0·269 81
0·359	0·595 7	0·271 68

Head h	Coefficient C_e	Discharge Q
m		$m^3/s \times 10^{-1}$
0·360	0·595 6	0·273 55
0·361	0·595 6	0·275 44
0·362	0·595 5	0·277 33
0·363	0·595 5	0·279 23
0·364	0·595 5	0·281 14
0·365	0·595 4	0·283 06
0·366	0·595 4	0·284 98
0·367	0·595 4	0·286 91
0·368	0·595 3	0·288 85
0·369	0·595 3	0·290 80
0·370	0·595 2	0·292 75
0·371	0·595 2	0·294 72
0·372	0·595 2	0·296 69
0·373	0·595 1	0·298 67
0·374	0·595 1	0·300 65
0·375	0·595 0	0·302 64
0·376	0·595 0	0·304 65
0·377	0·595 0	0·306 66
0·378	0·594 9	0·308 67
0·379	0·594 9	0·310 70
0·380	0·594 8	0·312 73
0·381	0·594 8	0·314 77

(*Continued from page 2*)

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